The Resurrection of a Biologically Dead Lake - a Case Study from Northern Sweden

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Abstract

A major release to surface water of heavy metals in Sweden is derived from oxidation of sulphidic waste- sand and wasterock. The lake Hornträsket in Northern Sweden has experienced a gradual loss of fish over the last three decades caused by leaching from abandoned Zn-Cu-mines. In 2002 a semi-quantative budget was brought forward which indicated one of three abandoned Z-Cu-mines as the major source of metals to the lake. Cu has been identified as the main toxicant and the proximity of the Hornträsk mine to the lake allows little retention of Cu before the drainage water reaches the lake. Several remediation measures have been tested and found to be partially successful such as diversion of drainage from upstream unpolluted runoff and neutralization of the coarse sulphidic waste rock by injection and sprinkling with mesa-chalk, a waste product from paper mills. This has resulted in decreasing levels of heavy metals in the lake and notably of Cu-concentrations. Removal of sulphide ore from some hotspots have been found necessary. It is expected that the fish population will recover in 5-10 years as a result of the remediation.

Key words: Mining, heavy metals, lake, fish, copper, liming

Introduction

Mining of sulphide ores poses threats to the environment by oxidation, acidification and release of metals to adjoining water bodies. This may seriously disturb the food web in lakes and streams, decreasing the biological diversity and cause accumulation of toxic metals in top predators. Via fish, metals could be transferred to humans. In Sweden there are two major sulphide mining areas, one in Central Sweden with the Falu copper mine that has been mined for more than 1000 years and the other is the Skellefte ore-field in Northern Sweden. In general the effluents from mining waste is discharged into rather large catchments neutralizing most of the acidity and leaving mostly more mobile heavy metal ions in the water like zinc and cadmium. The ecological effects on fish populations have been moderate and sometimes positive. In the lake Saxen with a zinc concentration past 1 mg/l the mercury content in pike was about 1/10 of what could be expected (Lindeström and Grahn, 1982). In the Skellefte ore-field mining has been going on since the 1920:s. Altogether about 60 M tons of ore has been mined and a similar amount is expected to occur above the depth of 700 m below ground. About 40 M ton of waste sand is deposited at mine sites and in addition to that large quantities of sulphidic waste rock. Lake Hornträsket is the largest lake that has suffered extinction of fish population due to mining waste.

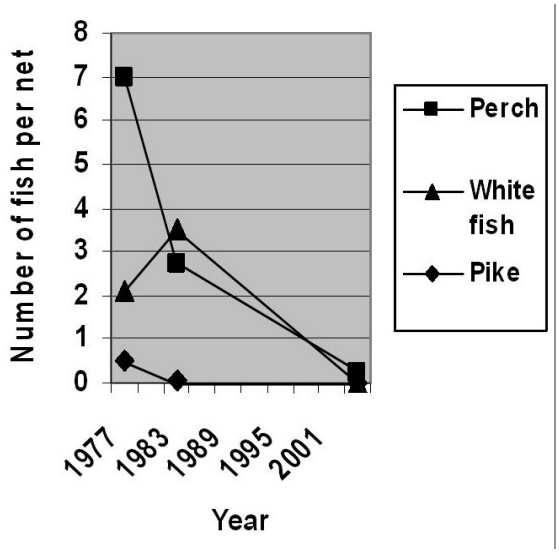
The aim of this article is to sum up the work done to restore Lake Hornträsket. It covers the process from assessing the problem via remediation efforts to a prediction of the likelihood of success.

Materials and Methods

Lake Hornträsket is a headwater lake having an area of 6.6 km^2 situated in a catchment covering 36.6 km^2 (Fig. 2). The catchment hosts three abandoned sulphide mine sites. Over a period of 27 years the lake has changed from having and abundance of pike, perch and whitefish to become more or less biologically dead. The results of standardized test fishing on three occasions are seen in fig. 1. A number of measures were taken to arrest the leaching of metals from two of the mine sites. At the Rävlidmyran mine site where 6.8 M ton of ore was mined an open pit lake was created of the mine opening (Ramstedt et al.,

2003); Lu, 2004). At the Hornträsket mine where 0.9 M ton was mined, the waste rock was used to fill up the three open pit mines and covered with a thin till cover. The third Granlunda mine is small and no remedial measures were taken. However, there is an extensive bog between the mine and the lake which is likely to adsorb any leached metals. In spite of the measures taken the water quality deteriorated rapidly mirrored in the decline of the fish population (Fig. 1).

Figure 1. Fish inventories in Hornträsk lake



Sampling has been done in more or less all the brooks and ditches feeding the lake and in a number of piezometers at mine sites. This investigation resulted in a semi-quantitative metal budget for the lake. The water budget was based on meteorological and hydrological data for the region. The distribution of metals in the lake was investigated by the installation of DGT probes from the ice in the late winter period and collected after three weeks.

The neutralization requirement of the mine waste was determined on mud from percussion drillings at a number of sites in the Hornträsk mine area. Dolomite and mesa-chalk, a waste product from paper mills, was mixed in different proportions with drilling mud and left standing until the pH was stable Sewage sludge was used in some treatments, mixed into the mesa-chalk slurry.

Results

The semi-quantitative budget showed that the Hornträsk mine was the major source of heavy metals to the lake. At Rävlidmyrgruvan the open pit lake does restrict oxidation (Ramstedt et al., 2003; Lu, 2004) and a sizeable retention occurs in wetlands before the drainage reaches the lake. The Hornträsk mine is situated close to the lake shore and part of the drainage water reaches the lake just after a few metres passage. The budget indicates a sizeable leaching from soils outside mining areas. This could come from the metasediments in the centre of the catchment (Fig. 2) which have sulphur contents in the order of 0.5-1 %. They are considerable sources of arsenic mobilized under reducing conditions in wetlands (Jacks et al., 2010). The arsenic is however largely retained in the streams where sandy sediments contain 200-400 mg/kg of As (Jacks et al., 2010). Much of the arsenic in streams and lakes is tied up to organic matter and colloidal ferric iron (Baur and Blodau, 2009).

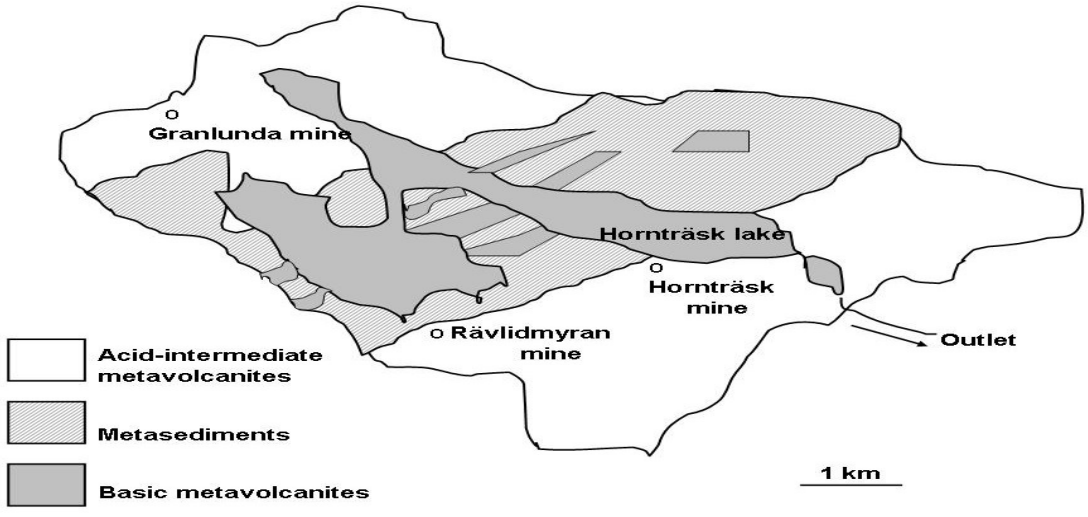


Figure 2. Geology and mine sites in the Hornträsk catchment.

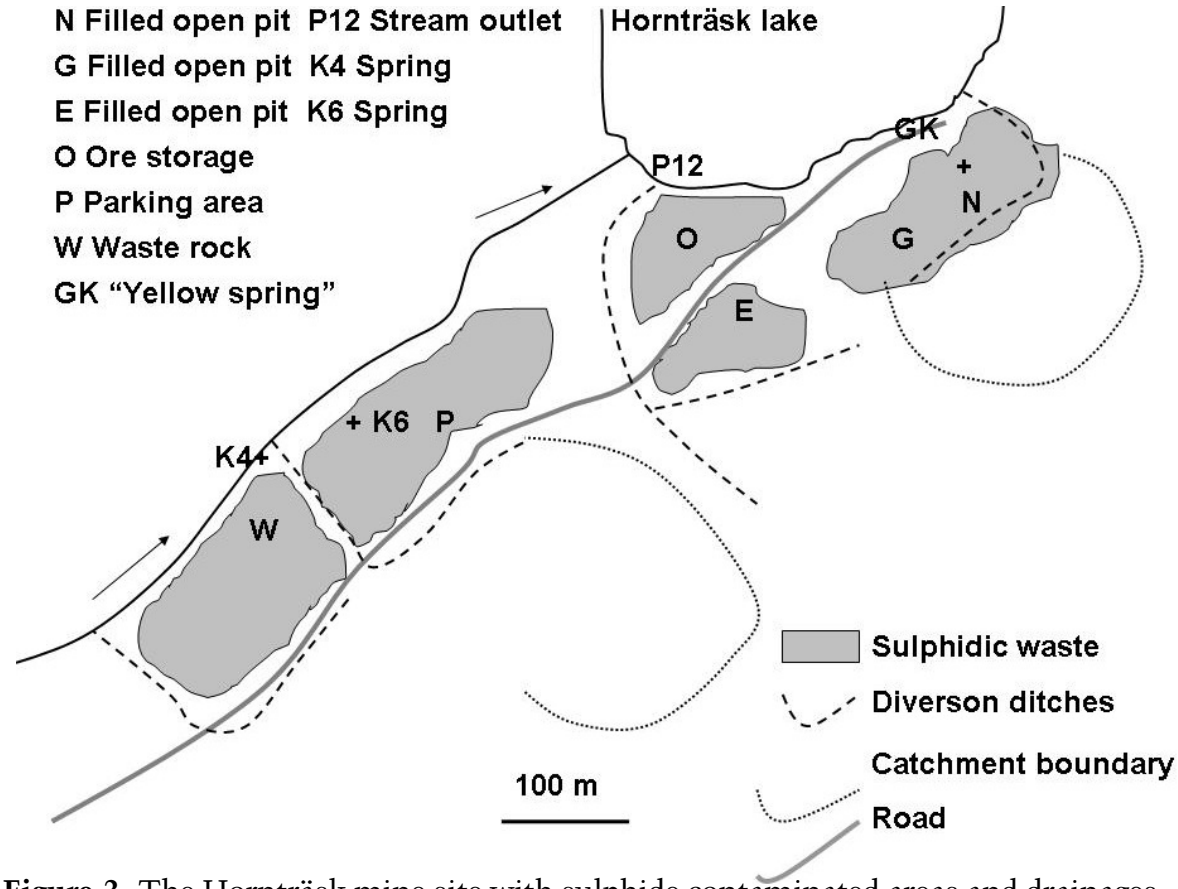


Figure 3. The Hornträsk mine site with sulphide contaminated areas and drainages.

From the relative concentrations the heavy metals found in the lake it is clear that the major threat to the aquatic fauna is Cu (Pierce and Spear, 1979; Bossuyt and Janssen, 2004). Zn can even have positive effects, decreasing mercury levels in fish (Lindeström and Grahn 1982). The metal budget indicated that the Hornträsk mine was the major source of Cu. Thus remediation measures have been focused on the Hornträsk mine.

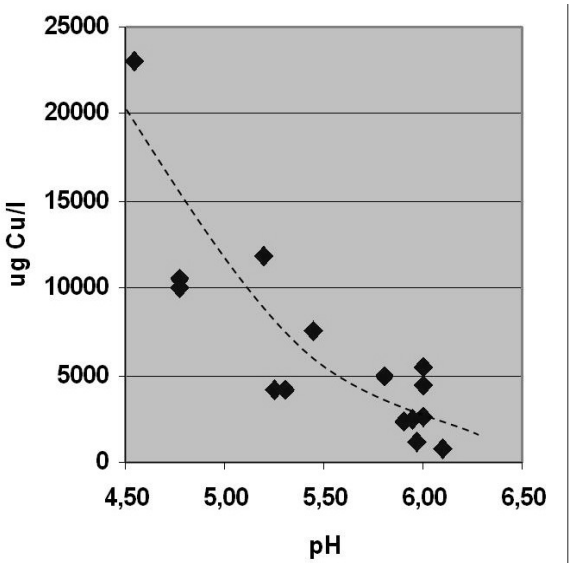


Figure 4. Effect of mesa-chalk treatment of open pit areas N and G.

The sulphide waste areas had non-conta- minated upstream areas which however caused an increased through-flow in the sulphidic waste material. Thus a first measure was to channel this drainage aside the sulphide areas (Fig. 3). This decreased the through-flow of the sulphidic waste by about 60 %. The second measure was an effort to neutralize the waste rock. It was first done by injecting mesa-chalk into wells installed in the waste rock. This worked well in the old open pit areas N, G and E (Fig. 3 and Fig. 4) but not in area P (Fig. 3) where it has later on been confirmed that ore has been stored. The alternate strategy was to sprinkle mesa-chalk slurry over this and other areas. The effect was good except again for the K6 spring discharge in the P area. The reason has been identified as hot spots of sulphide ore that has been localized by a dense network of piezometers.

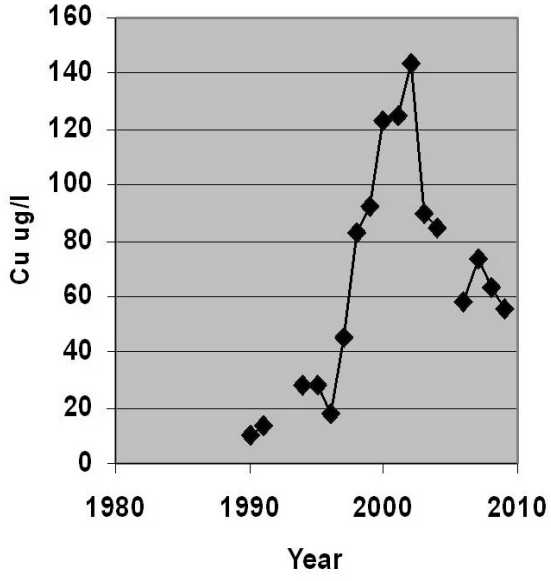


Figure 5. Totat Cu concentrations in the lake. Even before 1980 there were episodes of high Cu causing fish death.

The Cu concentrations in fig. 5 are total filterable concentrations. The DGT measurement indicates that the free toxic Cu concentrations are in the order of 40 % of these concentrations. If the total concentrations can be brought down to about 25 mg/l there is likelihood that most of the biological diversity in the lake can be restored (Baur and Blodau, 2009).

Conclusions

A lake lost its fish population through past episodes of metal discharge and a gradual increase of heavy metal discharge from 1995 to 2003 when remedial measures started. Cu was identified as the main toxic metal to the lake fauna and the Hornträsk mine was through a semi-quantitative metal budget identified as the major source of Cu to the lake. The remedial measures have included diversion of upstream inflow to the sulphide waste rock areas and neutralization of the waste rock by mesa-chalk, a waste product from paper mills. The injection of a slurry into wells worked well in the filled up open pits while it failed in an area where waste was deposited on peat, decreasing the permeability. This area also contains hot spots of sulphidic material which will be removed. The measures have decreased the lake concentration of Cu from 140 mg/l to 50 mg/l. The free Cu concentrations are in the order of 20 mg/l. It is expected that the exchange of water in the lake combined with the last measures, i.e. removal of a few hot spots of sulphidic waste will allow the recovery of the fish population within the coming 5-10 years.

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